APPENDIX F-1

PENNSYLVANIA NONROAD SOURCE EMISSIONS ESTIMATION METHODOLOGY

Bureau of Air Quality
Department of Environmental Protection
Division of Air Information

METHODOLOGY FOR ESTIMATING NONROAD EMISSIONS

I. INTRODUCTION

This following methodology provides a description of the procedures used to generate 2002, 2008, and 2009 county-level pollutant emission estimates for nonroad mobile engines included in the United States Environmental Protection Agency's (EPA's) NONROAD2005 model, as well as locomotive engines and aircraft operations. For the NONROAD2005 model engines, emission estimates were calculated for volatile organic compounds (VOCs), oxides of nitrogen (NO_x), and carbon monoxide (CO). Revised geographic allocation files for NONROAD model option files and revised housing unit data used for the model runs are also included.

II. 2002 NONROAD MODEL SOURCE CATEGORY EMISSIONS

The Department used EPA's Final NONROAD2005 Model to generate 2002, 2008, and 2009 summer work weekday emissions for the Philadelphia area, which includes Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties in Pennsylvania. The Department prepared NONROAD2005 model option files that account for temperatures and gasoline Reid vapor pressure (RVP) values representative of the Philadelphia 5-county area for summer weekdays. The Philadelphia 5-county area was treated as its own climactic zone. The average RVP value used for the 5-county area was 6.7. Minimum, maximum, and average temperatures for July for each region were obtained from the Pennsylvania State Climatologist website, Pennsylvania State Climatologist, Penn State University, *2002 Temperature Data by Weather Station* which is available at http://pasc.met.psu.edu/PA_Climatologist/cityform.html. The RVP and temperature inputs were applied to all equipment categories to obtain both summer day and annual emissions.

Table 1 lists the counties included in the Philadelphia area and the weather station where the temperature data were obtained for each of the regions. Table 2a and 2b presents the RVP and temperature data used in the model runs for each region of Pennsylvania.

Table 1. Regions of Pennsylvania and Associated Maintenance Areas

Region	Weather Station	Counties in Region	FIPSST	FIPSCNTY
Southeast	Philadelphia	Bucks County	42	017
		Chester County	42	029
		Delaware County	42	045
		Montgomery County	42	091
		Philadelphia County	42	101

Table 2a. Summer Day NONROAD Model Temperature and RVP Inputs

		Temperature*			
Region	**Season**	**Maximum**	**Minimum**	**Average**	**RVP****
Southeast	Summer	87	69	78	6.7

* Temperature in degrees Fahrenheit
** RVP in pounds per square inch (psi)

Table 2b. Annual Average Day NONROAD Model Temperature and RVP Inputs

	Temperature*			
Region	**Maximum**	**Minimum**	**Average**	**RVP****
Southeast	66	49	57	6.7

* Temperature in degrees Fahrenheit
** RVP in pounds per square inch (psi)

EPA-recommended diesel fuel sulfur levels for marine and land equipment for all years were used as inputs to the model, as outlined in *Diesel Fuel Sulfur Inputs for the Draft NONROAD2004 Model used in the 2004 Nonroad Diesel Engine Fuel Rule*, April 27, 2004. The 5-county Philadelphia area uses reformulated gasoline throughout much of the year. The Reid Vapor Pressure was assumed to be 6.7. The oxygenate requirement was eliminated in 2006. The oxygen percentage in gasoline was 2.0 percent in 2002 and 0.0 percent thereafter. Stage II vapor recovery was 100 percent in the 5-county Philadelphia area.

In past versions of the NONROAD model, state recreational marine vessels populations were underestimated when compared to boat registrations tracked by the Pennsylvania Fish and Boat Commission (PFBC). EPA's population of recreational marine vessels in the model now seem more representative of the number of boat registrations that the Pennsylvania Fish and Boat Commission tracks. We used EPA's default values in the model runs. We also examined geographic allocation factors for residential lawn and garden equipment. These improvements are discussed further in the next section. All other categories rely on default data included in the model for population and activity estimates.

<u>Residential Lawn and Garden Equipment</u>

The EPA's NONROAD2005 model uses 2003 U.S. Census data of all housing units in Pennsylvania to allocate residential lawn and garden equipment, even though EPA guidance states that emissions should be based only on the number of single detached, single attached, and double housing units. EPA's method in the NONROAD2005 model alters the allocation of lawn and garden emissions in some Pennsylvania counties significantly. The Department will use data obtained by E.H. Pechan from the 2000 Census, updated to 2002, and used in the state's 2002 inventory on the number of single detached, single attached, and double housing units for both the state and all counties in the state. Table 3 presents the Census data (Bureau of the Census, 2003), which can be found in *2000 County and State Housing Units by Unit Type, Census 2000,* http://factfinder.census.gov/servlet/. The total number of housing units was incorporated into the NONROAD2005 model geographic allocation factor file, PA HOUSE.ALO, for use in allocating state-level lawn and garden equipment populations to all Pennsylvania counties for 2002.

Table 3. Number of Single and Double-Family Housing Units from 2002 Census

County	# 1-Unit Detached Housing Units	# 1-Unit Attached Housing Units	# 2-Unit Housing Units	Total # of Housing Units
Adams	24,549	2,206	1,490	28,245
Allegheny	345,479	46,899	29,002	421,380
Armstrong	22,268	824	1,014	24,106
Beaver	54,418	2,312	2,863	59,593
Bedford	14,684	248	501	15,433
Berks	78,946	32,377	5,803	117,126
Blair	36,919	1,844	2,668	41,431
Bradford	16,861	232	1,224	18,317
Bucks	**141,951**	**30,506**	**5,425**	**177,882**
Butler	46,271	2,523	2,215	51,009
Cambria	44,453	3,795	2,882	51,130
Cameron	1,749	35	176	1,960
Carbon	14,431	5,104	990	20,525
Centre	27,786	2,691	1,749	32,226
Chester	**99,549**	**25,911**	**3,155**	**128,615**
Clarion	11,635	118	471	12,224
Clearfield	24,829	412	1,064	26,305
Clinton	10,141	662	711	11,514
Columbia	16,856	1,328	1,388	19,572
Crawford	24,430	397	1,933	26,760
Cumberland	51,934	10,450	2,792	65,176
Dauphin	52,961	20,195	3,848	77,004
Delaware	**93,642**	**64,529**	**9,361**	**167,532**
Elk	11,355	79	807	12,241
Erie	70,504	2,955	9,504	82,963
Fayette	41,679	3,094	2,473	47,246
Forest	1,660	8	18	1,686
Franklin	34,720	4,292	2,073	41,085
Fulton	4,084	56	133	4,273
Greene	10,387	481	416	11,284
Huntingdon	12,463	331	686	13,480
Indiana	23,215	825	1,232	25,272
Jefferson	14,276	237	729	15,242
Juniata	6,455	355	166	6,976
Lackawanna	53,357	3,328	12,626	69,311

Table 3. Number of Single and Double-Family Housing Units from 2002 Census

County	# 1-Unit Detached Housing Units	# 1-Unit Attached Housing Units	# 2-Unit Housing Units	Total # of Housing Units
Lancaster	98,364	32,122	7,370	137,856
Lawrence	28,316	799	1,489	30,604
Lebanon	27,272	8,647	2,225	38,144
Lehigh	59,753	29,474	5,118	94,345
Luzerne	82,363	15,404	9,435	107,202
Lycoming	31,568	2,812	2,998	37,378
McKean	13,794	158	972	14,924
Mercer	34,859	735	1,817	37,411
Mifflin	12,327	1,788	966	15,081
Monroe	40,696	1,726	1,457	43,879
Montgomery	**163,211**	**53,370**	**9,599**	**226,180**
Montour	4,769	645	346	5,760
Northampton	60,344	19,729	4,755	84,828
Northumberland	21,955	9,280	1,657	32,892
Perry	12,209	733	398	13,340
Philadelphia	**48,724**	**359,877**	**46,425**	**455,026**
Pike	15,501	395	299	16,195
Potter	5,263	62	281	5,606
Schuylkill	32,695	17,989	2,092	52,776
Snyder	10,263	644	526	11,433
Somerset	22,159	1,236	1,312	24,707
Sullivan	2,165	18	84	2,267
Susquehanna	12,139	180	711	13,030
Tioga	11,076	150	753	11,979
Union	9,341	652	527	10,520
Venango	17,197	227	1,080	18,504
Warren	13,031	239	930	14,200
Washington	60,711	3,891	3,187	67,789
Wayne	14,311	249	750	15,310
Westmoreland	113,694	4,839	5,997	124,530
Wyoming	7,858	159	412	8,429
York	95,921	20,218	6,102	122,241
Total	**2,724,746**	**860,086**	**235,658**	**3,820,490**

After the model runs, model outputs were processed to develop summer work weekday emissions inventories for NOx, VOC, and CO. Nonroad equipment refueling, either by portable container or at the gasoline pump, is being accounted for under Pennsylvania's area source inventory. As such, spillage and vapor displacement VOC emission estimates were subtracted from the total VOC emission estimates for all NONROAD Model emissions. Therefore, only exhaust, crankcase, and evaporative diurnal components are included in these VOC estimates.

Emissions from nonroad equipment were tabulated in both source classification code and category format. Immaterial rounding errors may exist when comparing the two formats due to different arithmetic operations performed inside and outside the NONROAD model for the two formats.

III. 2002 LOCOMOTIVE EMISSIONS

Much of the locomotive emissions were captured from a 1999 survey conducted by the Department included hydrocarbon (HC) and NO_x for the following locomotive source categories:

2285002006 : Railroad Equipment, Diesel, Line Haul Locomotives: Class I Operations
2285002007: Railroad Equipment, Diesel, Line Haul Locomotives: Class II/III Operations
2285002008: Railroad Equipment, Diesel, Line Haul Locomotives: Passenger Trains (Amtrak)
2285002010: Railroad Equipment, Diesel, Yard Locomotives

All line haul locomotive emissions were grouped into one SCC category in the appendix, 2285002005.

Norfolk Southern and CSX Corporations purchased Conrail. The takeover of Conrail's assets occurred in June 1999. For that reason, it was a very bad time to develop a representative emission inventory for these railroads. Both Conrail and Norfolk Southern suffered major gridlock in Pennsylvania and beyond during 1999. Consequently, fuel consumption and air emissions for these two railroads were greatly reduced in 1999. The Department requested and received 2002 fuel usage from these railroad companies and developed a 2002 emissions inventory for them. Fuel consumption increased 60 percent from 1999 to 2002. Clearly, this was not due to normal economic growth. All other emissions from railroad companies operating in Pennsylvania in 1999 were grown with a growth factor to obtain 2002 emissions.

To estimate 2004, 2009, and 2018 locomotive emissions, the Department projected the 2002 inventory to 2004 and beyond using national fuel consumption information supplied to the Department by the Association of American Railroads in combination with emissions factors developed by EPA and presented on the EPA website in the *Emissions Factors for Locomotives*, EPA420-F-97-051, December 1997, Table 9, Fleet Average Emission Factors For All Locomotives. According to the Association of American Railroads, national railroad annual fuel consumption has grown consistently at about 1.6 percent over the last 15 years. We used the following normalized emission growth factors for locomotive emissions. These numbers compare well with the EPA Economic Growth Analysis System (EGAS) 5.0 in the near-term. The only differences are that EGAS 5.0 forecasts a slightly larger reduction of NOx emissions in 2018 and a much larger VOC reduction in some future years. VOC emissions from locomotives are typically very small. EGAS 5.0 may be downloaded from http://www.epa.gov/ttn/ecas/egas5.htm.

Table 4. Normalized Growth Factors for Locomotives					
Year	**Fuel Use Growth**	**NOx Emission Factors**	**NOx Emission Growth (Fuel use growth * emission factor)**	**HC/VOC Emission Factors**	**HC/VOC Emission Growth (Fuel use growth * emission factor)**
2002	1.0000	1.0000	1.0000	1.0000	1.0000
2004	1.0323	0.8766	0.9049	1.0000	1.0323
2009	1.1175	0.6765	0.7560	0.8785	0.9817
2018	1.2891	0.5804	0.6553	0.7664	0.9880

In the Regulatory Support Document (RSD) for locomotive emission standards, national emissions account for future, phased-in controls that will primarily reduce NO_x and HC emissions as well (EPA, 1997). Emission reductions, which include rule effectiveness and rule penetration, are estimated based on the percent change in emissions from the base year to a given projection year. The Department reduces the 2002 locomotive emissions for NO_x and VOC by the percentages shown in Table 4.

To estimate VOC emissions from HC, the Department applied a VOC/HC conversion factor of 1.005 to the HC emissions. This conversion factor was obtained from EPA's *Documentation for Aircraft, Commercial Marine Vessel, Locomotive, and Other Nonroad Components of the National Emission Inventory, Volume I: Methodology* (EPA, 2002).

Estimated annual emissions were divided by 365 to obtain a daily emission estimate which was assumed to be a good estimate for emissions during an average summer day.

IV. AIRCRAFT EMISSIONS

Aircraft emissions at Philadelphia International Airport (PHL), the largest airport in the state, were estimated using the most up-to-date information available, which was supplied by the City of Philadelphia. Aircraft related emissions were also estimated for Northeast Philadelphia Airport (PNE) using up-to-date information. The methodology for estimating emissions at PHL and PNE is explained in greater detail in Appendix F2.

Small airport emission estimation methodology. Small aircraft emissions occurring at airports in Bucks, Chester, and Montgomery Counties were calculated by using small airport operation statistics, which can be found at www.airnav.com and the Federal Aviation Administration's (FAA) APO Terminal Area Forecast Detailed Report. Emission factors for a typical general aviation single engine, multi-engine, and jet engine aircraft were derived by averaging the emissions factors from a basket of emission factors for common aircraft of each of the three types of aircraft. Emission factors and operational characteristics contained in EDMS were used for this calculation. The proportion of operations between the three groups of aircraft was determined by examining the number of each aircraft type based at each airport. For military operations at small airports, the type of aircraft and its emission factors are sometimes identifiable. If not, emission factors calculated to represent an "average" military aircraft are used.

Growth at small airports was estimated using estimates of future operations contained in the FAA APO Terminal Area Forecast Detailed Report. The normalized growth in operations was applied directly to 2002 emissions to obtain growth in emissions. Changes in technology, such as new engine design, which may result in more or less emissions was not taken into account. Fleet mix may be slightly different in the future and this may also change emissions. This unpredictable effect was not taken into account.

Table 5. Normalized Growth in Aircraft Operations

County (Airport)	2002	2008	2009
Bucks County (Doylestown)	1.0000	1.0281	1.0377
Chester County (Chester County)	1.0000	1.0281	1.0377
Montgomery County (Perkiomen)	1.0000	1.0281	1.0377

Military aircraft. Willow Grove Naval Air Station is located in Bucks County. It is the source of significant air traffic and air emissions. It was estimated that NOx emissions were emitted at a rate of over one ton per day in 1990. Since the terrorist bombing of the World Trade Center, it has been difficult obtaining operations data from the military. The Navy refused to give the Department any operations data that would allow us to determine emissions produced from operations at Willow Grove. Therefore, emissions from Willow Grove are not included in our inventory.

V. COMMERCIAL MARINE VESSELS

Emissions from ship traffic in the Port of Philadelphia were estimated by using primarily the methodology outlined in the *Commercial Marine Activity for Deep Sea Ports in the United States, Final Report*[1]. A section in the report details the characteristics of ports on the Delaware River. Maritime Exchange for the Delaware River and Bay supplied ship arrival information. Ship arrivals for each pier, terminal, and facility were tabulated for the year in the report titled *Ship Arrivals for the Delaware River Ports 2003*[2], which included arrivals for years 1995-2003. Arrivals for 2002 were used for the 2002 inventory.

By mutual agreement between Pennsylvania and New Jersey, downbound traffic north of the Pennsylvania-Delaware border is included in the Pennsylvania emissions inventory while New Jersey captures all the upbound traffic north of the border. Most commercial marine vessel (CMV) emissions in the port are produced by hotelling emissions and tugboat trips. Ship shifts and large vessel movements do not contribute significantly to emissions. The pollutants that are produced in the largest quantity by ships are oxides of nitrogen (NOx).

Large Vessel Emissions

Large oceangoing vessels use Category 3 marine engines and use primarily distillate fuel.

The distance from the Delaware border for each shipping terminal was estimated using information on the U.S. Army Corps of Engineers website, at www.wrsc.usace.army.mil[3]. We followed EPA guidance for estimating the time required for a ship to travel the Delaware River from its berth to the Delaware border. All commercial ship traffic must slow to approximately 60-70 percent power around the time that they enter into Pennsylvania. This translates into 8 knots for tankers and 14 knots for container ships. An average speed of 11 knots was used for all ships. Once the vessel is within 3 to 4 miles of its intended berth or anchorage, it will continue at slow or dead-slow speed that ranges from 2 to 6 knots. We applied this methodology in reverse for a ship traveling out of its berth. An average speed of 4 knots was used for all vessels that are within 4 miles of their intended berth to calculate time for maneuvering. EPA guidance suggests that ships traveling with the current would travel three miles per hour faster than an upbound ship. Along the Delaware River near Philadelphia, speed limits are established in many areas that ships cannot exceed without causing damaging wakes. We assume river currents effect to be zero, because pilots will travel at 11 knots regardless since the speed limit is about 11 knots in many places

Equation for estimating time-in-mode:

$$\mathbf{T_{RSZ+MAN} = (D_{DB} - 4) / (S_{60\text{-}70\%} + S_{RC}) + 4/4}$$ [4]

Where:

$T_{RSZ+MAN}$ = Time-in-mode for reduced speed zone and for maneuvering.
$D_{DB} - 4$ = Distance to the Delaware border minus four miles needed for maneuvering speed (in nautical miles).
$(S_{60\text{-}70\%} + S_{RC})$ = Reduced speed plus the speed of the river current.
$4/4$ = Four miles for maneuvering divided by four knots

The length of time that each ship spent maneuvering in each county was calculated by finding the length of the river that runs by each county. Total maneuvering emissions were then apportioned to each county in the Philadelphia port.

Hotelling Emissions

Hotelling emissions from large CMV were calculated by determining the number and types of vessels that visited Pennsylvania ports. The average number of hours that each type of ship spends hotelling during a typical port visit was obtained from *Commercial Marine Activity for Deep Sea Ports in the United States, Final Report*[5]. Tugboats do not contribute to hotelling emissions. Fuel usage and emission factors for hotelling were obtained from *Procedures For Emission Inventory Preparation Volume IV: Mobile Sources*[6]. Emissions were distributed to the county level on the basis of the percentage of commercial vessel visits to each of the three Pennsylvania counties.

Tugboat Emissions

Tugboats use Category 2 marine engines and use primarily distillate fuel. Emissions from tugboat operations in the Port of Philadelphia were derived by using the total number of tugboat trips supplied by *the Waterborne Commerce of the United States*[7] report for calendar year 2002, found on the U.S. Army Corps of Engineers website. Average trip distances were estimated from this report. The report gives the approximate origin of the tugs. Many tugs are involved in lightering operations that are south of the Pennsylvania/Delaware border. Average trip times were estimated by using information obtained in telephone calls to tugboat operators in Port of Philadelphia and the equations provided in *Commercial Marine Activity for Deep Sea Ports in he United States, Final Report.* [8]

Tugboats were separated into six horsepower bins. Fuel usage was estimated by using information found in *Shipboard Marine Engines Emission Testing for the United States Coast Guard*. [9]

Table 6. Tugboat Fuel Use Characterization

Horsepower Bin	Number of Tugs in the Port	Fuel Usage (gal/hr)
0-750	7	25
750-1500	7	44
1500-3000	19	105
3000-5000	13	200
5000-8000	3	250
Total Tugs	49	

Emission factors from tugboats and pushboats are nearly nonexistent. *Commercial Marine Vessels Contributions to Emission Inventories*[10] suggested that 550 lb of NOx are produced per 1000 gallons of fuel used. CMV engines also known as type II marine engines are engineered and perform similarly to locomotive engines. Since some locomotive engines are the same size and operate under similar circumstances as tugboat engines, emission factors of locomotive engines were used at the suggestion of Greg Janssen of EPA[11]. Emission factors of locomotives from the U.S. EPA website, www.epa.gov[12] show NOx emissions at 609 lb per 1000 gallons of fuel. Since these tugs are under load like locomotives, the emission factors of locomotives seem more appropriate than other emission factors available. Other emission factors for hydrocarbons, and carbon monoxide were 50.6 lb and 80.3, respectively, for 1000 gallons of fuel consumed. Emission factors for tugboats were changed between the proposed version of the appendix and the final version of the appendix in order for the emission factors to remain consistent for these vessels statewide.

Distributing Tugboat Emissions to the County Level

The method outlined in allocating to the county level in *Commercial Marine Activity for Deep Sea Ports in the United States* [13] was not followed due to the geographic shape of the port. Delaware and Philadelphia counties get most of the emissions from commercial vessels since that is where most of the trips are recorded. The approximate number of tug trips to each county was estimated from trip statistics in *Waterborne Commerce of the United States* report[14]. Emissions were allocated to the county level as described by the equation below. Delaware and Philadelphia County had roughly the same amount of traffic while Bucks County had significantly less tug traffic.

Equation for Allocating Tugboat Emissions to the County Level

$\mathbf{T_{DC} = (TT_{PH} + TT_{CH} + TT_{SR}) / 2 + TT_{TH} / 3}$
Giving the example
T_{DC} = Hours tugboats spend traveling in Delaware County
TT_{PH} = Hours spent traveling from Philly Harbor to border
TT_{CH} = Hours spent traveling from Camden Harbor to border
TT_{SR} = Hours spent traveling from Schuylkill River to border
2 = Number of counties ships pass
TT_{TH} = Hours spent traveling from Trenton Harbor to border
3 = Number of counties ships pass
$\mathbf{T_{DC}}$ = (6584 + 19737 + 4794)/2 + 1820/3 = 16,164 hours

Ferry Emissions

Two ferries travel between Philadelphia and Camden seven times per day for eight months of the year. The vessels are idling and not emitting too much in the way of NOx for a large portion of their duty-cycle. Emissions standards for boats operating at low load and of comparable size were obtained from the *Shipboard Marine Engines Emission Testing for the United States Coast Guard-Final* Report[15].

Other Emissions

There is good reason to believe that significant emissions occur as a result of lightering emissions in the port. However, according to the Army Corps of Engineers and their consultant on the Delaware River Main Channel Deepening Project, Moffatt and Nichols, lightering operations occur south of the border between Pennsylvania and Delaware

The Coast Guard operates at least four vessels in the port, but it was impossible to obtain information on their operations.

The U.S. Army Corps of Engineers operates a dredging vessel in the Port of Philadelphia. The vessel, named Dredge McFarland, produced 197 tons of NOx and 60 tons of CO in 2002 according to the *Delaware River Main Channel Deepening Project: General Conformity and Mitigation* Analysis[16]. No other pollutants were given. It was impossible to ascertain exactly what percentage of time this ship spent in Pennsylvania. It was roughly estimated from the analysis that about 20 percent of the operations that occurred in the Philadelphia-Camden-Wilmington air basin occurred north of the Pennsylvania/Delaware border. Therefore, it is assumed that 10 percent of all dredging emissions occurred in Pennsylvania and 10 percent in New Jersey.

Emissions Growth

Emissions growth is based on two factors: future fuel consumption and future emissions standards. Emissions standards or programs that take place in the future will greatly lower emissions produced by CMV engines. Fuel use growth and future emission reductions used to calculate total future emissions were based upon information contained in the *Final Regulatory Impact Analysis: Control of Emissions from Marine Diesel Engines*.[17]

Fuel use growth for CMV was obtained from Table 5.8 for Category 2 engines, "Baseline Emissions from Category 2 CI Marine Engines Operated in U.S. Waters,"[18] and from Table 5-11 for Category 3 engines, "Baseline Emissions from Category 3 CI Marine Engines Operated in U.S. Waters,"[19] in the regulatory impact analysis. An average annual fuel use growth of 0.9 percent was estimated in the table for Category 2 engines and 1.0 percent for Category 3 engines, which led to corresponding baseline emission increases (absent controls) in carbon monoxide (CO), NOx, and VOC. Growth was based upon the number of extra CMV expected to enter service in future years.

In Table 5-14, which is entitled, "Total Emission Reductions from all Commercial CI Marine Engines," [20] the emission reductions for hydrocarbons were obtained for future years. The hydrocarbon reduction was applied directly to VOC emissions. Emission reductions in NOx were obtained from Table 5-9, "Projected NOx Emission Reductions from Category 2 CI Marine Engines Operated in U.S. Waters." [21] Table 5-9 was used for NOx because it shows emission reductions of Category 2 CI Marine Engines exclusively. Percentage reductions were derived from these two tables for VOC and NOx for use in the future years contained in our inventory. The tables gave reductions for 2010. We interpolated linearly between 2000 and 2010 to obtain reductions for our inventory's years of 2002, 2008, and 2009.

NOx reductions for Category 3 engines were obtained from Table 5-12, "Projected NOx Reductions from Category 3 CI Marine Engines Operated in U.S. Waters."[22] Emissions reductions were given for the year 2010. Emission reductions for the inventory were linearly interpolated for years 2008 and 2009. It was assumed that emission reductions of other pollutants except NOx produced by Category 3 engines were zero since no reductions for these pollutants were given.

Table 7 below shows the growth rates in emissions used to estimate emissions in the inventory.

		Table 7. Normalized Growth in Emissions for CMV in the U.S.					
		Normalized Future Emission Factors			Normalized Growth in Emissions (CMV Growth * Normalized Future Emission Factors)		
Year	CMV Fuel Use Growth	CO	NOx	VOC	CO	NOx	VOC
Category 2 Vessels (distillate fuel)							
2002	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2008	1.0552	1.0000	0.9800	0.9900	1.0181	0.9977	1.0079
2009	1.0647	1.0000	0.9600	0.9800	1.0647	1.0221	1.0434
Category 3 Vessels (residual fuel)							
2002	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2008	1.0847	1.0000	0.9462	1.0000	1.0847	1.0263	1.0847
2009	1.0957	1.0000	0.9397	1.0000	1.0957	1.0296	1.0957

[1] United States Environmental Protection Agency, Office of Mobile Sources, Assessment and Modeling Division, *Commercial Marine Activity for Deep Sea Ports in the United States, Final Report*, Ann Arbor, Michigan, June 30, 1999.

[2] *Ship Arrivals for the Delaware River Ports 2002,* Maritime Exchange for the Delaware River and Bay, 240-242 Cherry Street, Philadelphia PA 19106-1906

[3] U.S, Army Corps of Engineers, *Navigation Data* website, http://www.iwr.usace.army.mil/ndc/index.htm, July 19, 2001.

[4] United States Environmental Protection Agency, Office of Mobile Sources, Assessment and Modeling Division, *Commercial Marine Activity for Deep Sea Ports in the United States, Final Report*, pp. 8-5 - 8-6.

[5] United States Environmental Protection Agency, Office of Mobile Sources, Assessment and Modeling Division *Commercial Marine Activity for Deep Sea Ports in the United States, Final Report*, Table 8-5.

[6] U.S. Environmental Protection Agency, Office of Mobile Sources, *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources*, EPA-450/4-81-026d (Revised), , Ann Arbor Michigan, 1992, Chapter 7.

[7] Website of the Waterborne Commerce Statistics Center of the United States, United States Army Corps of Engineers, July 19, 2001.

[8] United States Environmental Protection Agency, Office of Mobile Sources, Assessment and Modeling Division, *Commercial Marine Activity for Deep Sea Ports in the United States, Final Report*, p. 8-5.

[9] Volpe National Transportation Systems Center and United States Coast Guard Headquarters Naval Engineering Division, prepared by Environmental Transportation Consultants, *Shipboard Marine Engines Emission Testing for the United States Coast Guard Final Report*, 1995.

[10] Booz-Allen & Hamilton Inc, Transportation Consulting Division, 523 West Sixth Street, Suite 616, Los Angeles, CA 90014, *Commercial Marine Vessel Contributions to Emission Inventories*, September 12, 1991.

[11] Email exchange with Greg Janssen of U.S. EPA, Office of Transportation and Air Quality, Assessment and Standards Division, Ann Arbor Michigan, January 24, 2001.

[12] U. S. EPA, Office of Transportation and Air Quality, website at http://www.epa.gov/otaq/locomotv.htm, July 19, 2001.

[12] U. S. EPA, Office of Transportation and Air Quality, website at http://www.epa.gov/otaq/locomotv.htm, July 19, 2001.

[13] United States Environmental Protection Agency, Office of Mobile Sources, Assessment and Modeling Division, *Commercial Marine Activity for Deep Sea Ports in the United States, Final Report*, p. 4-13.

[14] Website of the Waterborne Commerce Statistics Center of the United States, United States Army Corps of Engineers, July 19, 2001.

[15] Volpe National Transportation Systems Center and United States Coast Guard Headquarters Naval Engineering Division, prepared by Environmental Transportation Consultants, *Shipboard Marine Engines Emission Testing for the United states Coast Guard Final Report*, 1995

[16] Moffatt & Nichol, Walnut Creek, CA, *General Conformity Analysis and Mitigation Report, Final Draft*, February 2004.

[17] United States Environmental Protection Agency, Office of Mobile Sources, Engines and Compliance Division, *Final Regulatory Analysis: Control of Emissions from Marine Diesel Engines*, November 1999.

[18] Ibid., p. 109

[19] Ibid., p. 111

[20] Ibid., p. 115

[21] Ibid., p. 109

[22] Ibid., p. 112